Photo Interpretation and Mapping of Spruce Aphid Defoliation

FINAL REPORT

PHOTO INTERPRETATION AND MAPPING OF SPRUCE APHID DEFOLIATION

Project RMRS-99165-RJVA

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Submitted by:

David L. Kulhavy, Project Director
Arthur Temple College of Forestry
Stephen F. Austin State University
Nacogdoches, Texas 75962
(936) 468-3301 FAX (936) 468-2489 dkulhavy@sfasu.edu

James F. Ward, Project Associate
Arthur Temple College of Forestry
Stephen F. Austin State University
Nacogdoches, Texas 75962
(936) 468-3301 FAX (936) 468-2489

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PROJECT PURPOSE AND BACKGROUND

An outbreak of spruce aphid, *Elatobium abietinum*, occurred in the White Mountains of Arizona in 1996 and 1997, defoliating approximately 28,000 acres. This, presumably exotic, insect presents significant management and ecological problems including an increased risk of spruce beetle epidemic. The insect defoliates Englemann spruce and Colorado blue spruce but not Douglas-fir and subalpine fir. Large-scale color infrared aerial photography, supported with data gathered on site, and GIS was used to develop a hazard-rating system.

The spruce aphid has extended its range into the southwestern United States well beyond its previously known environmental limits. Of further concern is the fact that it has exceeded its known biological low temperature limits. This report presents the procedures that were followed for assessing the size and severity of the 1996-1997 outbreak of *Elatobium abietinum;* the conclusions derived from the data, and some recommendations for future work. The report also addresses procedures for developing a hazard-rating system. The hazard rating will be used as a management tool and/or a guide to further investigation, provided the correlation between defoliation, site and vegetation characteristics is significant.

Infestations of spruce aphid have occurred in Europe, the Pacific Northwest, and New Zealand, with economic damage occurring on Sitka spruce and white spruce. It was first reported in North America in 1916. North American distribution was limited to the Pacific and northwestern regions of the continent, and a single record from North Carolina. However, spruce aphid has become naturalized in the Southwest, or has been indigenous but unobserved until the late 1980's occurring primarily on Englemann spruce and occasionally on Colorado blue spruce. Defoliation occurs on all age classes of spruce (Lynch and Wilson 1999) and (Day and Kidd 1998).

OBJECTIVES

The objectives of the project were to delineate and label the aphid-effected areas, rate the

defoliation severity, and provide vegetation data analysis necessary for developing a hazard rating system.

MANAGEMENT CONCERNS

The White Mountains in eastern Arizona are managed for timber production, recreation, water and wildlife. Some of the concerns for spruce aphid expressed by resource managers are as follows (some effects might be positive):

- Fire hazard
- Tree mortality, especially in mistletoe-infected trees
- Pre-disposition to spruce beetle attack
- Visual effects, especially in ski valleys
- Changes in species composition
- Indirect effects to wildlife & wildlife habitats

For these reasons, and the more general concern of the health of spruce forests throughout the Rocky Mountains, a hazard rating for the spruce aphid is of great importance. In order to complete this task, two questions must be answered. How are the spruce aphid population incurring epizootics so far beyond its known ecological conditions and what part of the Englemann spruce distribution is at risk (Lynch and Wilson)? This project will provide some of the data necessary to answer these questions.

STUDY AREA

The study site is approximately 100 contiguous square miles in the Arizona White Mountains located near the Arizona/New Mexico border to the southeast of Springerville, AZ, on portions of twelve 7.5 minute quadrangle maps (Fig. 1). The western half of the site is located on the Fort Apache Indian Reservation and the eastern half is on the Apache National Forest, including the Mt. Baldy Wilderness Area. The area is covered with coniferous forest broken by patches of open grassland, referred to as cienegas.

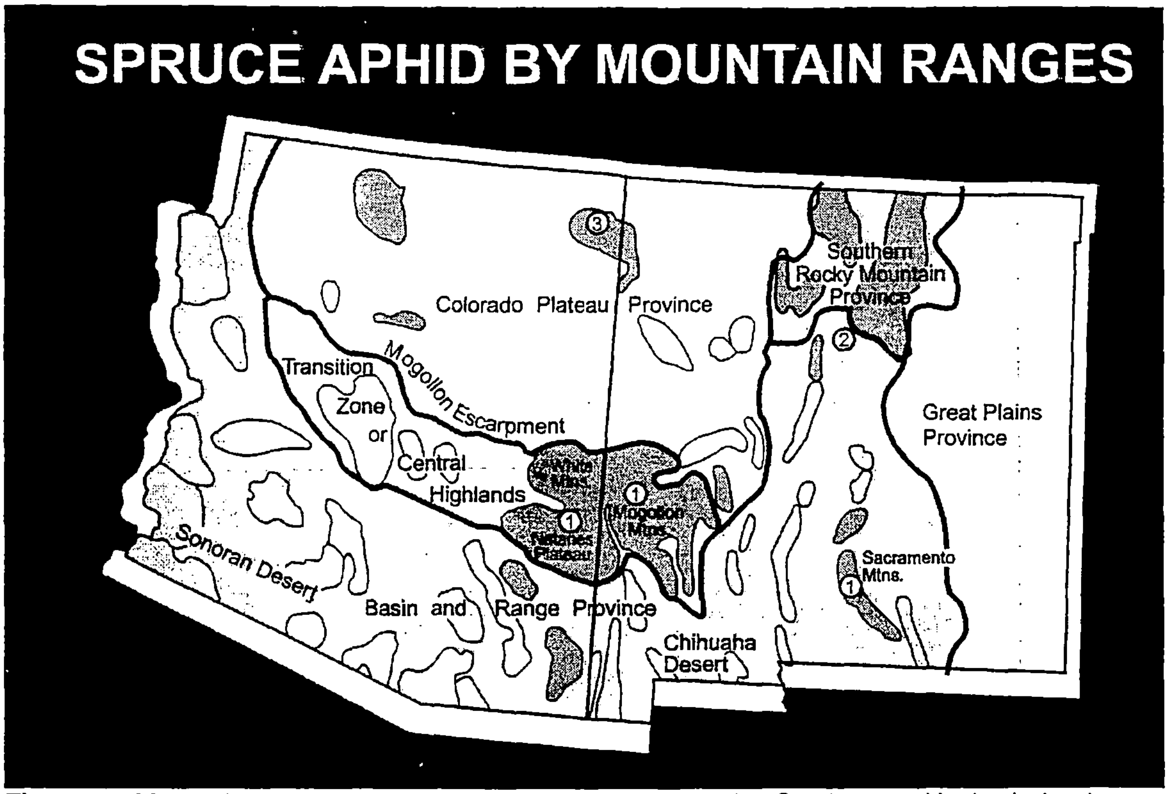

Figure 1. Mountain areas and spruce aphid infestations in the Southwest. Unshaded polygons are mountain ranges; shaded polygons depict areas with spruce zones. Circled numbers indicate (1) forest and (2) urban areas where spruce aphid has been observed and (3) forest areas where spruce aphid has been reported but not confirmed (Lynch and Wilson 1999).

PERSONELL, RESOURCES AND PROCEDURES

Stephen F. Austin State University Project Personnel

James F. Ward (doctoral candidate) was responsible for all of the photo interpretation for the project. In addition to his doctoral studies, Mr. Ward also owns and operates a natural resource mapping company in Nacogdoches, TX. Two of his key interpreters, Jay Hein and Steve Knepper, did a considerable amount of the aphid interpretation, however Mr. Ward reviewed all products submitted to the Forest Service. While Mr. Hein and Mr. Knepper did the aphid interpretation work, they were employees of Stephen F. Austin State University. Jay Hein also did most of the polygon transfer from the aerial photographs to the digital orthoquads using ArcView. James Ward may be reached at (409) 564-8865 or e-mail *jfward@netdot.com*.

Dr. David Kulhavy, professor of entomology, ecology and environmental science, oversaw the

project and provided guidance in developing the hazard rating system. He also served as the cooperator's technical representative. Dr. Kulhavy may be reached at (409) 468-3301 or e-mail *dkulhavy@sfasu.edu.*

Alan Smith, SFASU Graduate Student, did all of the GIS analysis for the project. He brought the data in from a variety of sources and software formats, placed it into ESRI's ArcView software, merged the appropriate data sources and created the final data sets.

Heather Osborne, a Stephen F. Austin State University undergraduate student, cut and sleeved photographs, transferred polygons from the photographs to the orthoquad registered overlays and placed a north arrow on each photo overlay. She also did a small amount of aphid interpretation that was closely reviewed by one of the more experienced interpreters.

Resources

The following resources were required to complete the project:

1) Twelve paper 1:24,0000 7.5 minute USGS black and white orthophoto quads showing the flight lines, the project boundary and photo frame numbers.
2) Polygons indicating the general location of spruce aphid defoliation on 1:120,000 scale paper maps
3) Over six hundred - 1:10,000 scale color infrared transparencies with 60% overlap and 30% sidelap flown by the R-2 USDA Forest Service.
4) Environmental Systems Research Institute's ARC/INFO software
5) LTDOS software for data capture and conversion
6) ArcView vegetation coverages of the Apache Indian Reservation and the Apache National Forest created by their respective agencies.

Procedures

Color infrared 1:10,000 scale aerial photographs (transparencies) were used to delineate and label spruce aphid outbreaks and their severity. Delineation of aphid infested trees was done within an effective area placed on every other photograph in a flight line and then transferred to a digital orthophotoquad using ArcView software on areas owned by the Apache NF. Digital orthophotoquads were not available on the Apache Indian Reservation; therefore transfer was done using a manual method to overlays registered to the paper orthoquads. This information was then used to develop a GIS-based rating system (Ward and Lovell 1997) and (Ward 1988).

Photo Preparation - A graduate student cut each frame (approximately 600 photographs) from three rolls and then inserted each one into a plastic sleeve and fastened it to the sleeve with drafting tape. Photos were sorted and filed by flight line and quadrangle map. The next step was to place an effective area on every other photograph. All delineation was done within the effective area.

Defoliation Interpretation - Five classes of defoliation (on host species only) were delineated on the overlays attached to the photographs (Table 1). Every other aerial photograph was delineated using either a Bausch and Lomb Zoom 240 stereoscope mounted on an MIM-4 light table or an Old Delft Scanning Stereoscope on a table top light table. The 1:10,000 scale is large enough to see crown structure, which makes the interpretation of defoliation damage a relatively simple task.

The photos were generally of good to excellent quality and portrayed the aphid damage very well. The only problems with the photography were sunspots, which are very difficult to avoid in large-scale photography, and an extreme angle of parallax. When the angle of parallax is too great the tops of tall objects will not be in stereo (three-dimensional viewing) when the base of the same object is in stereo.

Table 1: Spruce Aphid Defoliation Classification System

Defoliation

0	No defoliation
1	<25% defoliation of spruce in predominantly spruce stands
2	25-50% defoliation in predominantly spruce stands
3	>50% defoliation in predominantly spruce stands
4	<50% defoliation of spruce in non-predominantly spruce stands
5	>50% defoliation of spruce in non-predominantly spruce stands

Canopy closure

O 10-25% **P** 26-50% **N** 51-75% **G** 76-100%

Tree Size

V Very Large - >16"dbh

L Large – 9.0-15.9"dbh

M Medium – 5.0–8.9"dbh

S Small – 1.0-4.9"dbh

E Established seedlings – 0.0-0.9"dbh

Gathering Ground Truth Information - Ground truth information was gathered during a trip to the project area in June 2000. Dr. Ann Lynch, USDA Forest Service Entomologist, and Mr. Maury Williams, an Apache Indian Reservation Forester, hosted the trip. Ward, Hein and Knepper, SFASU photo interpreters, went on the trip to view the aphid infested spruce trees on the ground and then find the same trees on the aerial photographs thereby learning the appearance of the effected trees on the photos. Dr. Lynch and Mr. Williams were extremely familiar with the area and were able to show areas of various defoliation intensities to the interpreters.

Host Species Interpretation – In the original project plan, one interpreter was to delineate the defoliated areas, while another interpreter delineated the host species vegetation which included host species, size class and canopy closure (Table 1). However, while on the field trip, it was discovered that the Apache Indian Reservation already possessed what they considered to be excellent vegetation maps that contained the data required to complete this project. Furthermore, after returning to the University and making some calls to the Apache National Forest, it was discovered vegetation maps of equal quality were in the Forest GIS. Maury Williams supplied the vegetation maps of the reservation and Nancy Loving, GIS Specialist, supplied maps of the forest. While the maps are of equal quality, they were not edge matched and the classifications systems use a somewhat different legend. Alan Smith was able to visually smooth the edge match to an extent by giving the vegetation codes representing similar vegetation classes the same color.

One problem found after beginning the GIS work was the lack of the forest canopy closure and tree size fields desired for the ArcView analysis of data. Phone calls were made to request the desired fields and they should be received shortly at which time they will be integrated as individual fields into the GIS.

Figures 2 and 3 show a sample of the aerial photography complete with host species and aphid infested spruce stands. This work was done prior to the field trip by James Ward and was the planned procedure before acquiring the vegetation maps from the two previously mentioned agencies.

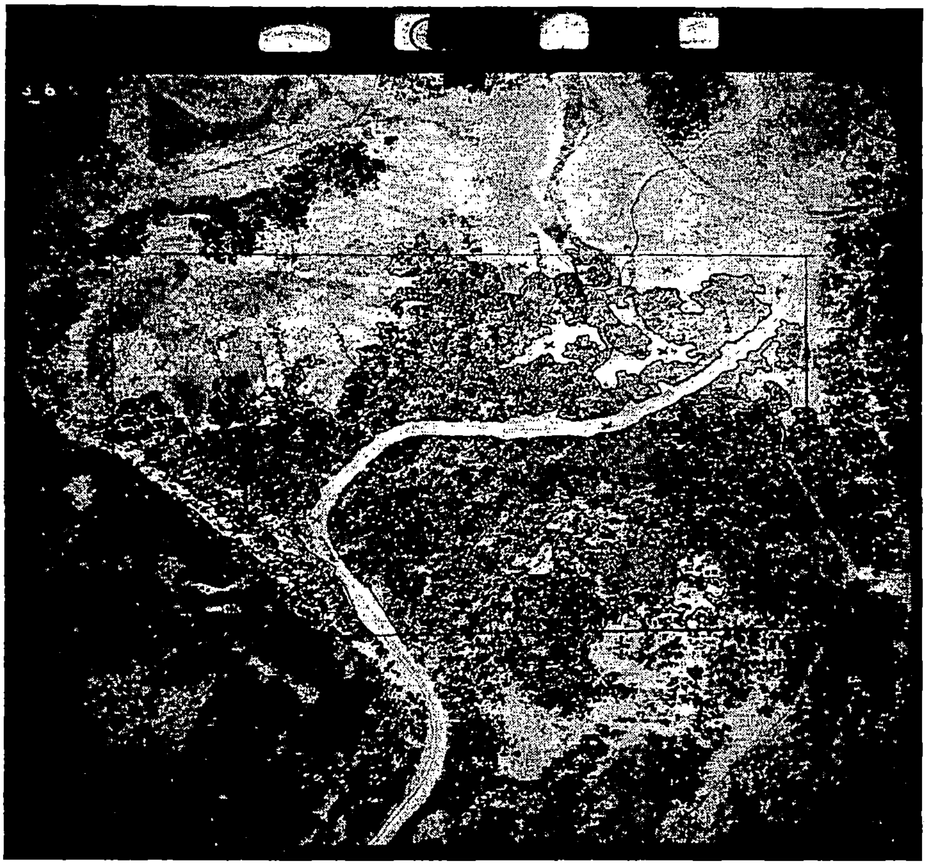

Figure 2. Land cover delineation interpreted from a color infrared transparency at an original scale of 1:10,000.

Figure 3. An enlarged portion from the above photograph to illustrate the appearance of normal and aphid infested spruce. Refer to Table 1 for label explanation.

Polygon Transfer - The task will be done using two methods because digital orthoquads were only available for those quads containing a part of the Apache NF. Only paper orthos were available for the portion of the project site covered by the Apache Indian Reservation. When digital orthos were not available, we used the first method which requires two steps to place the polygons into a GIS layer.

The first method was used when digital orthos were not available and involved using a Bausch and Lomb Stereo Zoom Transferscope. The transfer scope allows an interpreter to delineate polygons onto a mylar overlay registered and taped to a 1:24,000 orthophoto quad. The photographs were viewed in three dimensions and image detail, observed on both the photos and orthophotoquad was optically manipulated to fit the 1:10,000 scale photo on top of the 1:24,000 scale ortho image. Polygons were then precisely drawn onto the registered overlay by using the many control points supplied by the imagery. Polygons were drawn on the mylar overlays with a 000 radiograph. The interpreter now has a hand-drafted hardcopy overlay suitable for scanning.

The other type of transfer used was "on-screen" digitizing. This required the person doing the transfer to create a visual transfer of the polygons from the photographs to the digital orthoquad while viewed on the computer monitor. The mouse was then used to create a polygon on the screen that was matched to the same polygon on the photograph using image detail. Once this procedure was completed the polygons were placed into the digital format and became a GIS data layer.

There was sufficient detail on both types of imagery, photos and orthophoto quads, to provide an accurate transfer well within the USGS mapping standards using both methods of transfer.

Digitizing - Each of the 1:24,000 scale overlays were scanned at 300 dpi and saved as an RLC file. A data capture and conversion software titled LTDos was used to digitize the hand drafted quad registered polygons. The RLC files were brought into LTDos where the polygons were cleaned and refined before being converted from a raster image to vector data. Once the polygons were vectorized, an appropriate defoliation intensity attribute was assigned to each polygon. The finished overlays were then exported as a MOSS file, which is easily converted to an ARC file using a line command in ArcInfo.

Data Integration - The final step was to link the newly created spruce aphid defoliation intensity layer with terrestrial and vegetation databases, so that future analysis can correlate site and vegetation data to defoliation severity. Results of the photointerpretation effort, along with existing spatially referenced terrestrial data from other sources, was placed into a geographic

information system for spatial analysis and modeling. The models will allow researchers to develop ecological hypotheses from automated investigation of the databases (Aspinall 1994). Since the vegetation data came from two different sources, the Apache NF and the Apache Indian Reservation, different coding systems were used to indicate the same vegetation types. The types taken from both sources were aggregated into the following and given unique color codes that may be found in the accompanying ArcView CD.

- Agriculture
- Grassland
- Live oak
- Non-vegetated
- Mixed conifer with out spruce
- Riparian forest
- Riparian shrub and herbaceous
- Aspen
- Spruce
- Treeland (undetermined types)
- Douglas-fir
- Other hardwood
- Water

HAZARD RATING SYSTEM

The hazard rating system discussed in this paragraph is in the future tense because SFASU is waiting for delivery of the canopy density and tree size GIS fields. Once received and integrated into the GIS each forest stand can be given a hazard rating code. It will be a numeric code that will represent a trend from no hazard (lowest number) to extreme hazard (highest number) and used to predict the susceptibility of a given stand to the spruce aphid. By using what we have learned through this study, forest managers should be able to extrapolate the combined criteria creating the hazard code into other similar forest locations. The code will be a combination of landform, proximity to certain landscape features, tree size, stand composition, canopy density and weather data. It may be necessary to weight the mapping criteria. Different combinations of environmental and vegetation factors may result in the same numeric hazard rating. Theoretically, recommendations based upon the results of the hazard rating could be made to effectively manage the spruce aphid (Coster and Searcy 1974).

RESULTS

GIS analysis of the data produced the following results:

- 1,565 individual polygons were interpreted into five defoliation intensity levels
- A total of 27,657,470.2 square meters were defoliated
- The average size of a polygon was 17,672.5 square meters with a variance of 642758730.54 and a standard deviation equaling 25352.69
- The minimum polygon was 509.21 square meters and the maximum was 298,123.87 which produced a range of 297,614.66 square meters.

The above polygons were then placed into their appropriate intensity levels

Hazard Class	No. of Polygons	Area Mean Sq. Meters	Area Sum Sq. Meters
0	13	5,364.20	69,734.55
1	617	15,338.55	9,463,885.81
2	421	20,485.52	8,624,402.10
3	125	19,728.10	2,466,001.19
4	370	18,201.14	6,734,422.74
5	19	15,738.09	299,023.71

Polygons classified as Undetermined Areas, Hardwoods and Agriculture did not have spruce aphid.

Polygons classified as Live Oak/ Grass had the following ratings:

Hazard Class	No. of Polygons	Area Mean Sq. Meters
0	6	17,907.01
1	238	15,338.55
2	255	20,485.52
3	90	19,728.10
4	197	18,201.14
5	20	15,738.09

Polygons classified as Grass had the following ratings:

Hazard Class	No. of Polygons	Area Mean Sq. Meters
0	6	17,907.01

Polygons classified as Aspen had the following ratings:

Hazard Class	No. of Polygons	Area Mean Sq. Meters
0	1	2305.91
1	69	30,359,47
2	75	34,766.49
3	22	36,256.45
4	58	56,212.79
5	13	18,041.74

Polygons classified as Spruce had the following ratings:

Hazard Class	No. of Polygons	Area Mean Sq. Meters
0	5	5894.63
1	451	17,493.11
2	336	29,026.23
3	111	27,118.30
4	183	30,528.32
5	9	28,307.97

Polygons classified as Riparian had the following ratings:

Hazard Class	No. of Polygons	Area Mean Sq. Meters
0	0	
1	42	22,967.98
2	29	57,172.79
3	6	36,527.01
4	8	18,348.66
5	1	3,359.80

Polygons classified as Pine/ Mixed Conifers had the following ratings:

Hazard Class	No. of Polygons	Area Mean Sq. Meters
0	9	10,681.49
1	405	24,111.91
2	249	39,800.09
3	102	39,482.55
4	300	26,617.83
5	14	13,835.20

Polygons classified as Douglas-fir had the following ratings:

Hazard Class	No. of Polygons	Area Mean Sq. Meters
0	2	1234.12
1	123	23,338.16
2	61	24,797.79
3	15	20,007.11
4	136	32,353.55
5	1	51,744.15

When the project was in its planning and preliminary phase two presentations were made as follows:

1. James Ward presented a poster titled "Assessment of an *Elatobium abietinum* outbreak in the Arizona White Mountains Using Aerial Photography" for the USDA Forest Service RS 2000 Conference in Albuquerque, NM. The poster was accepted for publication within the Conference Proceedings by the American Society of Photogrammetry and Remote Sensing and co-authored by James F. Ward, David L. Kulhavy, Ann Lynch and Jill Wilson.

2. David Kulhavy presented a summary of the project plan at the East Texas Forest Entomology Seminar, Kurth Lake, TX in May 2000.

Conclusions

- The 1:10,000 color infrared photography was easy to use and delivered a very good representation of the defoliated trees. The Old Delft Scanning Stereoscope and the Bausch and Lomb Zoom 240 stereoscopes worked very well and should be good for similar future projects. A pocket stereoscope does not work well when using transparencies because the interpreter needs to be able to overlap the photographs, and obviously transparencies are not suited for overlap. It would also be tiresome to use and cause unnecessary fatigue.

- The most common shape of a polygon was an irregular elongated ellipsoid with the long axis parallel to some sort of an opening in the forest canopy, a stream, or perpendicular to the slope of a mountain side. Interpreters noticed that many of the spruce aphid polygons occurred adjacent to grass meadows or cienegas.

- As with all photointerpretation projects there is some error. The error may be categorized as omission or commission error. Omission error is when some of the spruce aphid defoliated trees were overlooked, confused with defoliation on other host species or occurred in groups too small to map. This should be fairly minimal as each photograph was carefully examined. Commission error is when spruce aphid defoliation includes defoliation from other sources. The interpreters believe this to be more common than omission error because when Douglas-fir and Englemann spruce are growing near one another and both have been defoliated, its is difficult to tell them apart on the photographs. It was not possible for our interpreters to distinguish the causal agent of defoliation. For example, when on the field trip, interpreters

saw defoliation in one stand caused by bear girdling, bark beetles, dwarf mistletoe and spruce aphid.

- Vegetation maps supplied to the University by the Apache Indian Reservation and the Apache NF were assumed to be accurate. Our project interpreters are not aware of any fields within the GIS that provide a percent composition of tree species within a stand. If there is a mixed stand of spruce and Douglas-fir, it may be indicated on the GIS vegetation layer as a Douglas-fir stand. The user of this product should not assume that if a spruce aphid light to medium intensity polygon is overlaying a Douglas-fir stand it is in error.

Recommendations

1. Further GIS analysis should be conducted in order to maximize the data and discover more information about the spruce aphid and its effect on spruce stands, the forest and the broader landscape in general. Ancillary data to be integrated should at least include:

- A Digital Elevation Model (DEM) used to obtain landform information such as elevation, aspect and slope. Much of this data can be extracted from the DEM using Arc/Info software.

- Soils maps.

- Spatial weather data such as temperature, precipitation, barometric pressure, and prevailing wind patterns.

- Proximity of the spruce aphid polygons to natural canopy openings, streams, lakes, and other significant corridors. This should then be compared to manmade openings such as ski runs (the defoliation was large and intense at the Reservation ski resort) roads, pipelines, powerlines, etc.

The following are some examples of data queries that may be made for analysis using the above mentioned factors:

- Position of outbreaks within the general study area,
- Shape and location of the outbreaks in relation to temperature and wind direction,
- Shape and location of the outbreaks in relation to soil type,

- Age, condition, size and stand density of the infested spruce,
- Percent composition of species within a defoliated stand.

These are but a few of the many combinations of data that should be examined.

2. A statistical accuracy assessment of the final photointerpretation product should be done to ascertain the percent correct classification. This effort would require additional funding and was not a part of the current contract.

3. Use a smaller scale aerial photograph. A rule of thumb for photo interpretation is to use the smallest scale imagery possible while still being able to identify the detail necessary to full fill the objectives of the project. Interpreters could identify the defoliated trees using 1:12,000 to 1:15,840 photographs provided the resolution remained the same. If the interpreter needs to see structure within the tree crown, the current 1:10,000 is probably a good scale. By reducing the scale, the photo acquisition would cost significantly less as well as the interpretation. A smaller scale will also lessen the angle of parallax and reduce the effect of sunspots. The CIR transparency or film positive is much better than working with paper prints and should be maintained for any future projects.

4. When possible, use digital orthophotoquads. For projects such as this one when only a few polygons are delineated on a photograph, the "on-screen" digitizing is faster and more cost efficient then transferring using the ZTS. The digital orthos were of good quality very easy to use.

5. Compare a sampling method developed on the same study site with the 100% coverage method used for this project. It may be beneficial to the Forest Service to determine if a sampling technique could be developed that would come close to the accuracy achieved using the 100% coverage method.

6. Investigate the proximity of the defoliated trees to cienegas to determine the significance, if any, to the occurrence of spruce aphid. It could be that this is where most of the spruce trees are concentrated because of an optimal soil type, more moisture and cooler temperatures. Another option could be the effect of a wind born insect being dropped where the trees create a drag

REFERENCES

Aspinall, R. J., 1994. GIS and Spatial Analysis for Ecological Modeling. In W. K. Michener, J. W. Brunt, S. G. Stafford (eds.), Environmental Information Management and Analysis: Ecosystem to Global Scales.

Coster, Jack E. and Janet L. Searcy editors, 1974. Site, Stand and Host Characteristics of Southern Pine Beetle Infestations. United States Dept. of Agriculture, Combined Forest Pest Research and Development Program. Technical Bulletin No. 1612.

Day, K. R. and Kidd N. C. 1998. Green spruce aphid population dynamics: effects of climate, weather and regulation. Pp. 41-52 in Day, K.R., and Halldorsson, G. (Editors), The Green Spruce Aphid in Western Europe: Ecology, Status, Impacts and Prospects for Management. Forestry Commission Technical Paper 24, Edinburgh.

Lynch, Ann M., and Jill L. Wilson, 1999. Spruce Aphid (*Elatobium Abietinum* (Walker)) Populations Reach Epidemic Levels on *Picea Engelmannii* Parry in the Southwest United States. Journal of Agriculture and Forest Entomology. (In Preparation).

Ward, James F., 1988. Forest Pest Management Photointerpretation Training Manual. Remote Sensing Applications Center, USDA Forest Service, Salt Lake City, UT and Forest Pest Management Methods Application Group, USDA Forest Service, Ft. Collins, CO.

Ward, James F. and David Lovell, 1997. Custer County Colorado Riparian Mapping – Final Report. Colorado Division of Wildlife, Colorado Springs, CO.